
Automation of zircon blasting for barrel and receiver combination

Investment project



Ammattikorkeakoulun opinnäytetyö

Mechanical Engineering and Production Technology

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ABSTRACT

The purpose of this thesis was to produce a plan to automate zircon blasting. The target was to improve the convenience and safety of work, reduce the amount of zircon dust escaping the cell, produce unmanned production time and increase production capacity. The project was commissioned by Sako Ltd, a factory specialized in rifle production, located on the same site in Riihimäki since 1921. For the author, choosing this thesis was the obvious choice, having worked in the factory for over 3 years. In addition, the author already knew how zircon blasting works, and how it could, and should, be improved.

The project was implemented as a part of production method planning. With zircon blasting as an operational cell, yet without any greater automation, it created a challenge to come up with a cost efficient plan for automating it by recycling as much current equipment as possible. A budget was never set for the project. It was designed to be carried out if the calculations for repayment met the cost of the equipment needed.

Zircon blasting was designed to be automated with a robot using PLC for independent work, while worker labor was to be limited to loading and unloading products with all machines fully operational at all times. It turned out that the real challenge was to prevent zircon beads from building up on dimensional surfaces or entering spaces where they could do harm to mechanisms, as well as how to make the whole project cost efficient enough to be carried on.

Possible future investments were also taken into consideration while working on the project. This included a plan to add a washing machine for stainless steel products into the same cell, and to design automation for belt grinder.

Keywords Bead blasting, automation, rifle production, work efficiency

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TIIVISTELMÄ

Opinnäytetyöprojektissa suunniteltiin zirconpuhalluksen automatisointia. Tavoitteena oli parantaa työskentelyn mielekkyyttä ja työturvallisuutta, vähentää zirconpölyn määrää tehtaassa, tuottaa miehittämätöntä koneaikaa sekä nostaa tuotantokapasiteettia. Projektin tarjoajana toimi Sako Oy, Riihimäellä sijaitseva kiväärituotantoon erikoistunut tehdas, joka on toiminut samalla tehdasalueella jo vuodesta 1921. Allekirjoittaneelle opinnäytetyön valinta oli helppo, sillä olen toiminut tehtaan työntekijänä jo yli kolme vuotta. Lisäksi olen työssäni päässyt hyvin tutustumaan zirconpuhallukseen ja siihen miten sitä pitäisi parantaa.

Projekti toteutettiin osana tuotannon menetelmäsuunnittelua. Zirconpuhalluksen jo toimiessa, toki ilman suurempaa automatisointia, loi haasteen tuottaa kustannustehokas automatisointisuunnitelma kierrättämällä mahdollisimman paljon nykyistä toimivaa kalustoa. Varsinaista budjettia ei työlle asetettu, vaan projektin toteutuminen päätettäisiin vertaamalla takaisinmaksuaikalaskelmia laitteisto- ja suunnitelmamaksuihin.

Puhallus suunniteltiin automatisoitavaksi robotin avulla, joka ohjelmoitavalla logiikalla kykenisi itsenäiseen työhön työntekijän ladatessa ja purkaessa tuotteita järjestelmän käydessä. Haasteiksi muodostui zirconrakeiden kasautuminen mittapinnoille ja niiden pääseminen paikkoihin missä ne voisivat tuottaa haittaa mekaniikoille, sekä työsyklin suunnittelu mahdollisimman kustannustehokkaaksi.

Huomioon otettiin myös mahdolliset tulevaisuuden näkymät, joissa samaan soluun, saman robotin toimialueelle, ollaan suunnittelemassa myös ruostumattomasta teräksestä valmistettujen tuotteiden pesu, sekä mahdollisesti myös automaattinen hiekkapaperinauhauus.

Avainsanat Raepuhallus, automatisointi, kiväärituotanto, työteho

Sivut 24 s. + liitteet 2 s.

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Appendix 2 CLOCKING ZIRCON BLASTING

1 INTRODUCTION

The topic of the thesis came from a need to improve and automate zircon blasting for barrel and receiver combinations within Sako Ltd factory in Riihimäki.

Before starting on the project, blasting was done by manually inserting products into blasting cabinets where automated, cylinder operated, blasting nozzles treated the products by blasting zircon beads on visible surfaces. Manual insertion required unnecessary overreaching from the employees into the blasting cabinets, which caused muscle aches and joint pains. Working inside, as well as close to the cabinets, also predisposed employees to breathing zircon dust, a result of which filter masks were necessary for everybody working in the cell. Getting rid of a method where barrels were fixated on the rotation mechanism from their muzzles, which often left muzzles scratched, as zircon beads got stuck between the two surfaces, was also on the table. And, as always, there was a need to produce unmanned production time and ultimately increase production capacity. For many years in a row, the production volume of rifles has increased in the industry, and specifically in Sako Ltd.

With the company switching its production methods into customer order based and storage free, the ease of production was to be especially taken into account while designing the automation for the thesis. Zircon blasting of barrel and receiver combinations should succeed without any major changes in the production hardware while switching from profile to another. As a principle, the only acceptable change in hardware, while switching from one product model to another, is to attach the adapters from a different hole. During the project, different possibilities to produce the same kind of surface quality, as the zircon blasting cell produced when starting the project, were carefully examined. All this was while attempting to lower costs and increase the volume of production. The placement of the cell remained unchanged in the factory. This meant that the project was to be designed from start to finish as a whole.

While the equipment produced was to be tested thoroughly, for both functionality and the quality they produced before moving into the factory, the break-in and training needed to happen without any major halts in the production. Automating the whole cell would require several machines working with each other, but controlling the cell was to be designed easy enough for an untrained employee to be able to operate - without a risk of causing any unnecessary harm, even by an accident, to the products or the production line itself. Work cycle needed to be continuous, so the investment would repay itself as soon as possible.

Planning to attach a washer for stainless steel products within the same cell has already started. A washing machine, which would operate in the domain of the robot arm, would take a lot of space, so it had to be taken into consideration while preparing the layout of the blasting cell. Also, belt grinding for barrel and receiver combinations is to be automated in the future, which affected the way adapters were designed.

2 WORK CYCLE AND CAPACITY

The main goal in the thesis was to improve how zircon blasting is executed on barrel and receiver combinations. Replacing blasting cabinets did not automatically mean that the actual blasting would have been any faster. Production capacity was meant to be increased by dividing zircon flow into three nozzles, designing a robot arm to load and unload both cabinets and by designing an automated adapter setter to operate as a logistic storage space between the employee and the robot arm.

2.1 Previous work cycle

As the work started on the thesis, the zircon blasting cell contained two cabinets for blasting, both designed to house six products in horizontal position. Two air compressor units with zircon containers, two vacuums for dust, a dryer for the compressed air and operating tables, on which to insert and remove adapters and plugs, were also positioned right next to the cabinets.

The work started by lifting products on the operating table in series of six. Barrels were plugged from the cartridge chamber to prevent zircon from destroying the rifling within, and adapters were attached to receivers. Products were then moved into the correct cabinet, according to the raw materials used, and clamped from the adapter to the mouth of the barrel, where a small rubber plug prevented any zircon from entering the rifling. The cabinet housed six products total, and all needed to be the same exact length as the clamps holding the products moved on rails as a single unit.

Information on the products loaded, needed to be passed on to the control. Control station had buttons for rotation speed and the amount of barrels inserted. Also, the control needed to know how long the inserted barrels were. This was notified by manually moving the nozzles into correct position in the mouth of the barrel, thus teaching the program where to turn. After everything was set, the blasting was initiated.

Two nozzles moved to the muzzle side of the products and started blasting surfaces with zircon, while the machine started to spin the barrels with high speed. Nozzles moved along the barrels, onto receivers and when finished, moved to next two products. At the same time, employee started to prepare next six barrel and receiver combinations for production by attach-

ing adapters. After blasting was finished, a light indicated that the cabinet could be opened, and finished products were unclamped from the machine and moved to the operating table to be inspected for surface quality and to have the plugs and adapters removed.

2.2 Designed work cycle

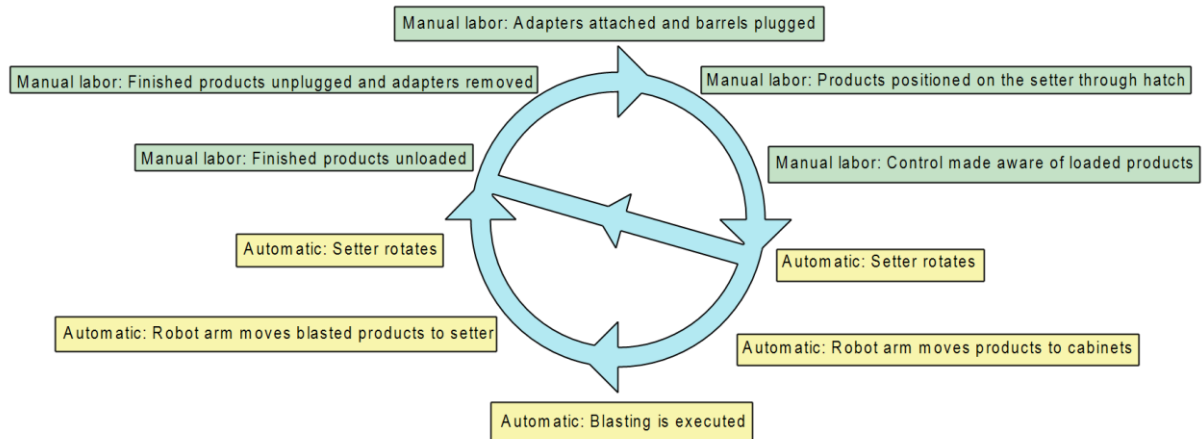
New cabinets are designed to house barrel and receiver combinations vertically, thus saving a lot of space in the blasting cell. With the cabinets smaller in volume as the previous, the need for two vacuums was removed. Next to the operating table, a small rack was designed for products attached to adapters. The rack is for the employee to fill while blasting is underway, removing downtime from production and creating free time off from the blasting machinery.

The employee starts by filling up the operating table with barrel and receiver combinations. Adapters are attached from designated holes with a single screw, and barrels are plugged from both ends. The safety fence has a hatch on it, which when opened, opens a view to a single side of a six sided rotating setter, which houses six products on each side. Barrel and receiver combinations are hanged on the setter from the adapters, making it easy for the robot to grab a hold on them. When products have been loaded onto the setter, hatch is closed and information on the products is inserted on a small control panel located right next to the hatch. Control needs to know the material of the products, as well as the thickness of the barrels. Thanks to applied technology, there is no need to insert the amount of products inserted, nor the length of the barrels. After all is set, the blasting cycle can be started.

The setter rotates 180°, and a robot arm starts lifting products into the correct blasting cabinet. If all six places in the setter are not filled, the robot simply reaches for air and quickly moves to try the next spot without setting up any alarms. At the same time, if the setter side turned to the hatch is either filled with finished products or empty (and is not reserved for products in a blasting cabinet), the hatch can be opened for unloading and loading more products. When the robot has finished loading, door closes on the cabinet and air compressors start blasting products with zircon.

Three nozzles start moving down from the top of the cabinet, treating the receivers first while moving onto barrels and eventually all the way down to the muzzles. Small ultra-sonic sensors attached at the bottom of the nozzles detect the length of the barrels, and the blasting is stopped as the longest barrel has been completely treated. After that the nozzles move on to next three barrels and start to blast them from muzzles up. When blasting is finished, nozzles move to their starting position and cabinet door is opened. If the robot is currently unoccupied, it unloads the finished products on to the setter. In the next available situation, the setter rotates fin-

ished products to the hatch for unloading, quality inspection and removal of adapters and plugs.



Picture 1 Designed work cycle

2.3 Production capacity

Compared to the previous blasting system, production was calculated to increase by 221% with the newly designed system. While the actual speed of the linear thrust could not be increased due to high requirements in surface quality, all excess movement done by conveyors were eliminated and zircon flow was divided into three nozzles, thus decreasing time it takes to surface treat six barrel and receiver combinations. The overall automation added into the plan was like adding a second employee to blasting cell. If the plan is to work out perfectly, the actual manual labor will be reduced to merely attaching and detaching adapters, loading and unloading the setter and keeping eye on surface quality, while the machine blasts away products, stopping only to reload its content.

The old cell has two separate blasting cabinets, just like in the new system. However, in the old system both cabinets are not clocked to be operated at the same time. This is because the required time to prepare products and then unload and load them into cabinets is too much for one employee to handle. Fortunately this won't be a problem with the designed system. With both cabinets fully operated by the robot arm, the increase in production capacity would be enormous.

3 ABRASIVE BLASTING

Abrasive blasting is a method, where a stream of abrasive material is forcibly transported against a surface under high pressure to smoothen out a rough surface, roughen up a smooth surface, shape a surface in a specified way or remove materials from harder surfaces. A pressurized material, typically air or water, or a centrifugal wheel is used to transport the blasting abrasives. Typical variants of the process are bead blasting, sandblast-

ing, soda blasting and shot blasting. Blasting equipment typically includes three essential components: an abrasive container, a propelling device and a blasting nozzle or nozzles. Sand used to be the most common material as a blasting abrasive, but with the pneumonic disease silicosis being caused by extended inhalation of the dust created by sand, other materials are used nowadays. All small and relatively uniform particles work as abrasives, and materials used in blasting can be classified as sand, slag, metallic shot or grit, synthetic and other.

- Silica sand abrasive is commonly used where reusing the sand is not possible, such as in unconfined sandblasting. Sand has a rather high breakdown rate, which can result in major dust generation. Employees have a high danger of exposing themselves to crystalline silica when silica sand is used for abrasive blasting.
- Slag abrasives are used where expendable abrasives are required for on-site abrasive blasting. Slags have the advantage of low silica content, but release other contaminants, including hazardous air pollutants into the air.
- Metallic abrasives include cast iron shot, cast iron grit and steel shot. Cast iron is harder and more brittle compared to steel shot, which on the other hand is much more durable. These materials typically are reclaimed and reused.
- Synthetic abrasives, such as silicon carbide, aluminum oxide and zirconium, have become popular substitutes for sand. These abrasives are more durable and create less dust than sand, and are typically also reclaimed and reused.
- Other abrasives include mineral abrasives, cut plastics, glass beads, crushed glass and nutshells. As with metallic and synthetic abrasives, these abrasives are generally used in operations where the material is reused. Mineral abrasives create significantly less dust than sand and slag abrasives.

Due to the dangers of inhaling dust, sandblasting is carefully controlled using an alternate air supply, protective wear, and proper ventilation, and the blasting is usually done in a closed environment, away from outsiders.

3.1 History

The process of sandblasting was first patented in the United States in 1870. Back then, actual sand was sieved to uniform size and used as an abrasive, hence the term - sandblasting. Fortunately the use of this method was halted after its link between respiratory diseases was found. By 1893, the air processor helped bring sandblasting into industrial use, and improvements to the process continued throughout the 20th century. By 1939, quartz, aluminum oxide and silicon carbide were used as mediums for sandblasting material. Thereafter, softer media such as walnut shells and fruit stones were explored. Industries began using glass beads and plastic abrasives for surface treatment.

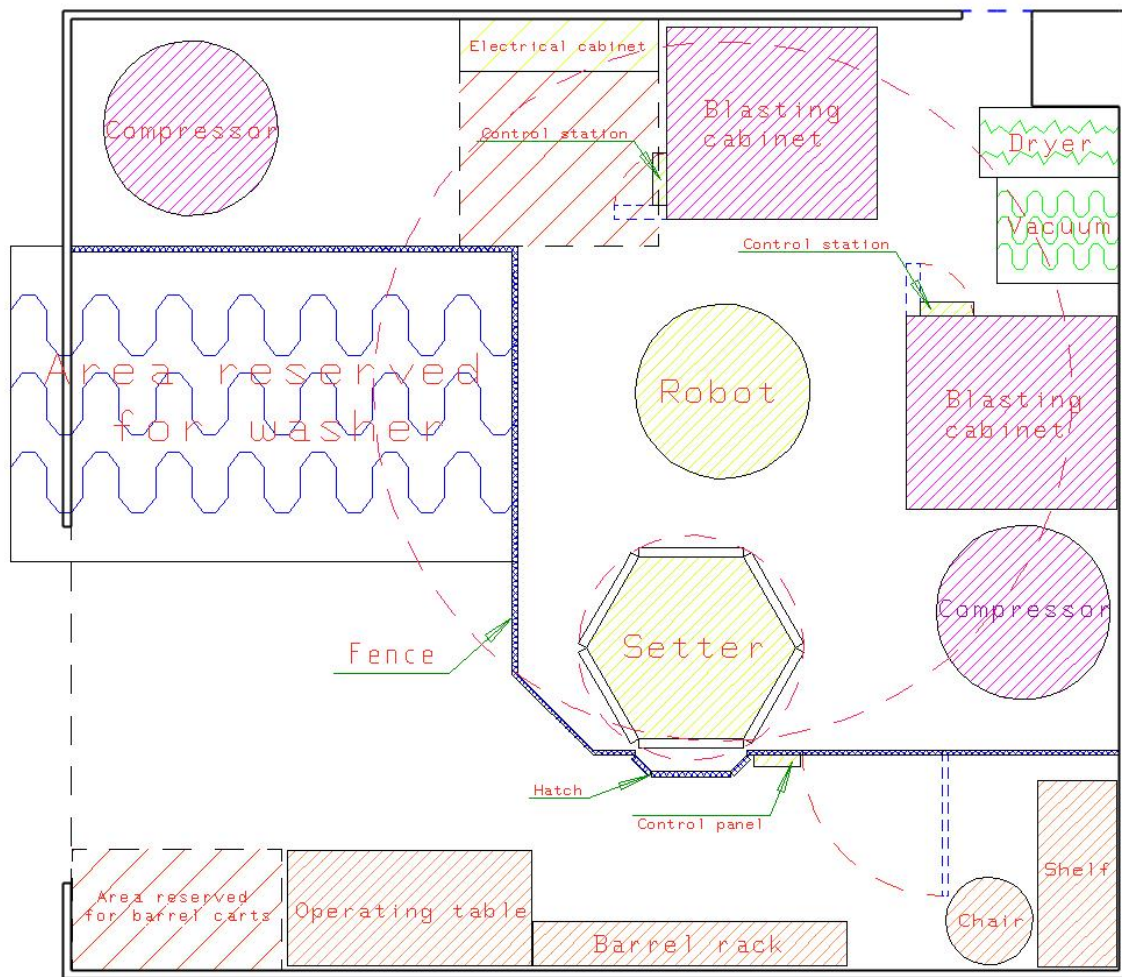
3.2 Zircon blasting

The method used in the factory is zircon blasting. Small ceramic beads are applied on product surfaces with the help of pressurized air. Blasting is executed in a closed environment, blasting cabinet, and all beads are fully recycled in the system. Products are blasted to achieve a specified surface roughness. It is not meant to clean anything or smoothen out small cracks or flaws in the surface, because unlike popular fallacy, bead blasting does not make those flaws disappear, but on the contrary makes them more visible to human eye. Surface roughness achieved reflects a little less light and simply looks better.

4 LAYOUT

The blasting cell in the factory is 5,86m x 5,54m, wall surrounded, yet a roofless area with a sizeable sliding door. For safety reasons a large cage is designed to house the robot and the rotating setter inside the cell. Two blasting cabinets are connected to the cage for the robot to operate. Air compressors with zircon containers for cabinets, vacuum machinery, drier for compressed air, operating table and a rack are also designed to locate within the walled cell.

All equipment is placed so that there is enough room for the employee to attend all necessary maintenance required daily, and those which need more maintenance than others are placed for easier access. If the walled area is found insufficient in space, there is a possibility to move the walls, thus expanding the cell area. This will probably become reality at the latest when the washing machine is connected to the automation. Walls are there only to keep zircon from spreading into rest of the factory, where it might cause damage to machinery or machined parts. On the other hand the area is roofless, which questions the whole theory of containing the dust. If the new blasting system is found to be airtight enough, and therefore does not release zircon dust into the factory, the need for walls will be removed.



Picture 2 Designed blasting cell layout

4.1 Safety fence

To prevent employees from any unnecessary harm, a safety fence was designed to house the robot arm and setter in the blasting cell. In addition to just the moving robots, blasting cabinets, air compressors, vacuum and air dryer were all moved inside the fence in the plan. This was to simplify the fence layout, and to prevent any unnecessary meddling with the equipment. Fence is to have 2 entrances on it: A door and a hatch, both equipped with electrical locks and safety switches. If walls are removed from the cell in the future, the fence is to be extended so that it surrounds the blasting equipment as a whole.

4.1.1 Fence door

The fence is to have a single door, which the employee will use for repairs and maintenance, as well as in any emergency event that needs a human hand. In addition to having just a handle operated opening mechanism the door will have an electrical lock, which will unlock only if it's told to do

so by pressing an intended button on the control panel, or by activating an emergency stop button. Pressing the door opening button on the control panel drives the robot arm into its home position, halts the rotation of the adapter setter and only then is the door unlocked. The door cannot be unlocked if the power is out from the system, and the robot arm will not move to its home position immediately if it is currently holding a product when the button is pressed. Instead, it will finish the movement it was doing (loading or unloading a product), and move to home position after that. System saves the information on what was being done in the cell when the door was unlocked, and when the door is closed and a button is pressed to ensure that all personnel have left the caged area, production will continue from the point it was halt at. If the control faces an emergency, such as in case of a fire, all work is saved into its memory, all production halted and the door is unlocked.

4.1.2 Hatch

As the employee needs to be able to load and unload the system while blasting is underway, a hatch was added to the plan. A small portion of the fence is to be cut, and a hatch made out of see-thru plastics, which would slide up and down on rails by human force is to be placed on the resulted hole. The hatch is to also have an electrical lock on it, which will be operated by the control. A small light, located right next to the hatch, is to light up when the setter on the other side of the hatch is about to start revolving. This will also lock the hatch. As the setter has revolved enough and comes to a halt, the lock will open and the light will turn off, indicating that the hatch is free to be opened for unloading and loading. The lock also keeps the control up-to-date whether the hatch is open or closed. This is to prevent the setter from revolving if the hatch is open or was left open unintentionally. In an ideal situation employee opens the hatch only to unload already surface treated products and quickly refills the now empty slots with new barrel and receiver combinations.

4.2 Blasting cabinet

Current cabinets in the blasting cell are horizontal models. This means that the products are inserted inside horizontally and are zircon blasted from above, while barrels rotate with fastened adapters. Doors are opened manually, and control of the machinery is based solely on teaching the program. The biggest problems with current cabinets are:

- the lack of flexibility in the way blasting is executed
- scratches in muzzles of barrels, which is a result of rubber plugs not rotating with the barrels because of zircon beads get stuck in the axels
- difficult method of inserting products into the machine, resulting in back pains on employees

- pointless movement of the muzzles inside which decreases production capacity
- leakage of zircon dust from door seaming

4.2.1 Cabinet

The designed cabinet is 1,18m x 1,06m x 3,91m in size, stainless steel product, and is capable of blasting six barrel and receiver combinations at one time. Both sides of the cabinet have large windows to ease manual setting and programming. It is designed so that the products can be loaded in vertically, thus saving a lot of space in the cell. In all cases possible, actuators are positioned outside of the cabinet to protect them from zircon beads and dust. All holes, in addition to the door, are sealed with brushes to make the cabinet as dustproof as possible. Bottom is cone shaped to ensure a good bead flow, and has a metal shield to help vacuum separate dust from beads. Inside of the cabinet is coated with rubber mattress to ward off wearing in the walls.

4.2.2 Cabinet door

Manually and horizontally opened door is replaced in the design with a pneumatically and automatically opened vertical hatch. Control is supposed to work so that the hatch opens and closes as needed by the robot arm. A pneumatic cylinder is placed on top of the cabinet which, when lengthened, lifts the hatch up. A pneumatic wedge activates when the door is closed, and by forcibly pushing the door to its frames fully seals all seaming so that no zircon is able to escape the cabinet while blasting is initiated.

4.3 Blasting equipment

During planning, the blasting compressors used were found to be capable of compressing enough air to operate three nozzles instead of the two used before. This opened a possibility to cut down production time greatly, as well as offered an option to use same blasting equipment as before, thus saving in expenses. However, since repayment calculations indicated such short payback periods, it was found to be profitable and safer to order new, modern equipment.

The pressurizing system used before was found to be excellent and needed no tweaking, so it will be crudely copied into the new equipment. Overall, the old system seemed to have worked well for years, so everything new planned was heavily based on the old. An option opened where the divination of zircon flow into three could be executed by inserting three valves on the bottom of the new blasting tank. The method was found to be too

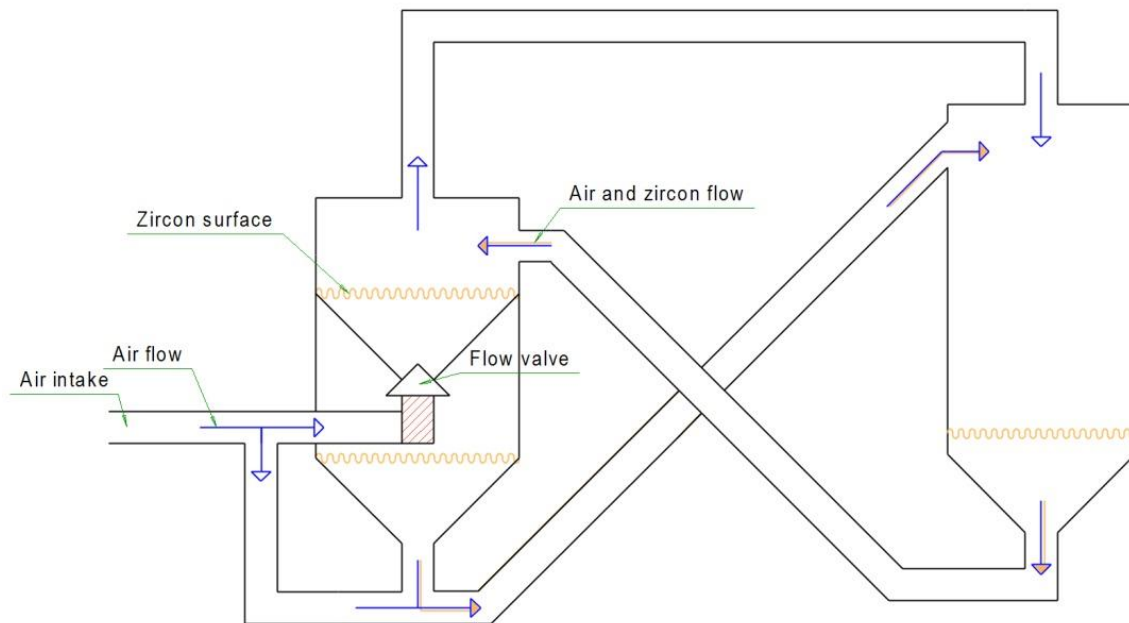
expensive to be carried out in the first phases of testing the new equipment, but could be added into the system later in the future.

4.3.1 Compressor tanks

Current compressors are a combination of two main parts:

- Bead tank for incoming zircon
- Bead tank for outgoing zircon

Beads used in the system are fully recycled. As employee adds beads in the bottom of the blasting cabinet, it's moved to the incoming zircon tank in the compressor by pressurized air. Bottom of this tank has a flow valve, which is shut while zircon blasting is underway. This increases the air pressure in the cycle. After blasting is done and air is no longer guided into the system, the valve opens, allowing beads used to flow down onto the tank for outgoing zircon. When the system is restarted, valve is once again shut, and zircon in the outgoing tank is used for the blasting. The designed equipment is very similar to the old ones, hold up to 100 liters of zircon, and operate in the same way.

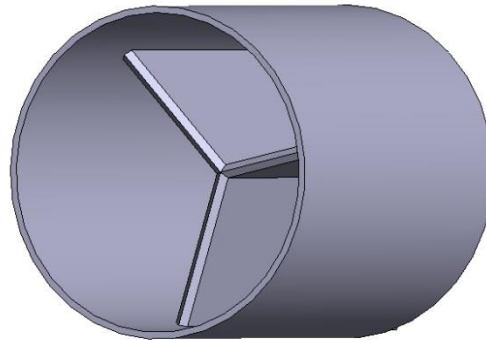


Picture 3 Air and bead flow in the blasting cycle

4.3.2 Nozzles

Zircon is blasted through three nozzles of 6mm in diameter each, aimed carefully at surfaces on barrels and receivers. The tube diameter is at 4mm in diameter at its lowest, but increases to 6mm to create a cone for the out bursting beads. Nozzles are attached to pneumatic pistons, which move them horizontally as well as vertically inside the cabinet. A valve, also pneumatically operated, is used to switch the angle of the nozzles. This is to ensure that beads reach even the most difficult corners in the receivers.

Previously, blasting was done with two nozzles only, so a method for dividing bead flow into three was needed. By squeezing tubes and molding them to look like one third of a circular tube, it is possible to weld three of those tubes together, forming a larger tube with a perfect division into three. In the process, an option opened where the division could be bypassed by inserting three valves onto bottom of the blasting tank. This will ensure a steady flow for all nozzles. Replacing blasting tanks was found to be too expensive, and a tube split method will be used at least in the first phases of testing the system.



Picture 4 Sketch of the 3-way flow splitter

4.3.3 Pneumatic cylinders

Inside the cabinet, nozzles are moved vertically with a pneumatic cylinder placed on the roof of the cabinet. Another piston is placed horizontally also on the roof, which moves the railed vertical piston from one point to another and back, making it possible to insert six products in the cabinet at the same time. Entry point of the piston into the cabinet is sealed with a heavy row of sealing brushes, to ensure that the minimum amount of beads and zircon dust escape the blasting cabinet. Another vertically inserted cylinder is used to automatically open and close the door of the cabinet.

4.3.4 Magnetic separation filter

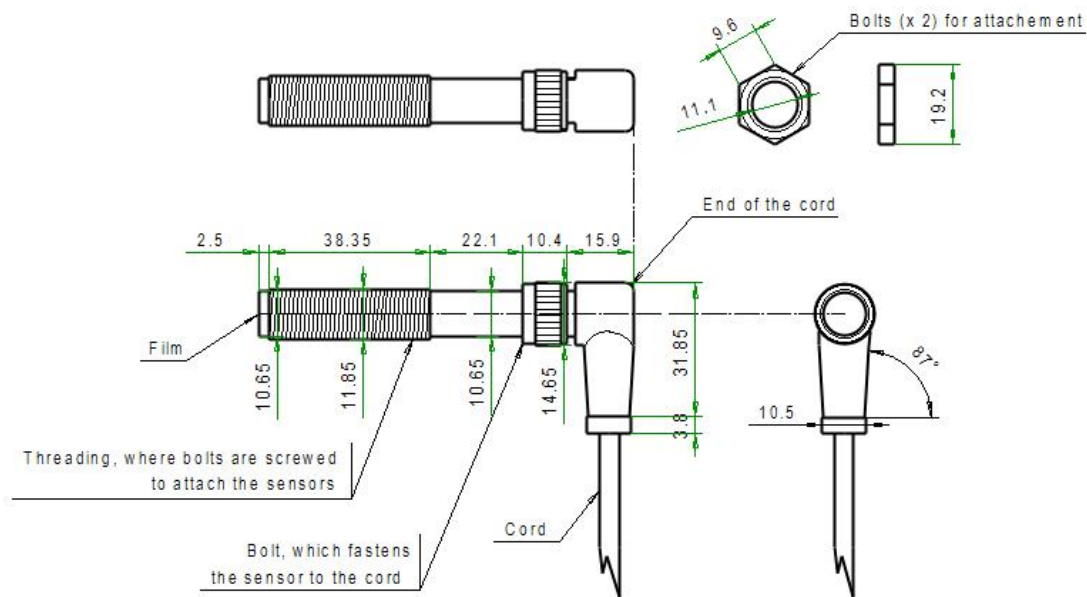
Zircon blasting is done in two different sets of equipment because two different raw materials are used on the products. Stainless steel products cannot be put in the same cabinet where black steel products are being blasted. This is due to beads removing microscopic particles from product surfaces, which causes rusting in stainless steels if black metal particles end up on them, because unlike black steels, stainless steels are not surface treated for corrosion. A possibility to add a magnetic separation filter to the system was investigated. This kind of filter would, with a help of a

magnet, remove all speckles of steel from the bead flow, thus making it possible to zircon blast both material products in the same cabinet. While the idea might sound good, magnets have very low effect on stainless steels. Therefore the idea had to be rejected. While it might filter out all black steel from the flow, the stainless steel speckles would end up on black steel products. All black steel products are blackened after zircon blasting, and stainless steel has a very high resistance to blackening chemicals. The result would look patchy, as black steel products would be blackened, while stainless steel speckles in them would remain unchanged. Rejecting the idea of blasting all products in the same cabinet is not considered a big deal, since two cabinets are needed anyway to keep up with the increasing need for production capacity.

4.3.5 Ultrasonic sensors

To cut down all extra work from the system, ultrasonic sensors were designed to be attached to the side of the blasting nozzles. Small sensors would pulse knowledge on whether there is still a barrel to blast or not. When all three sensors tell the control that all products have been blasted, nozzles would move automatically to next three barrels. There, sensors determine the length of the longest barrel, and blasting is done according to given information. Without the use of sensors, barrel lengths must be divided into several categories (e.g. 20", 23", 28"), and a button must be added into the control panel, where employee inserts the length of the longest barrel he/she just inserted into the blasting circulation. This doesn't eliminate the possibility to insert barrels of different length into the system at the same time, but might increase production time if even one of the barrels is longer than the others, since all must be blasted according to the length of the longest one.

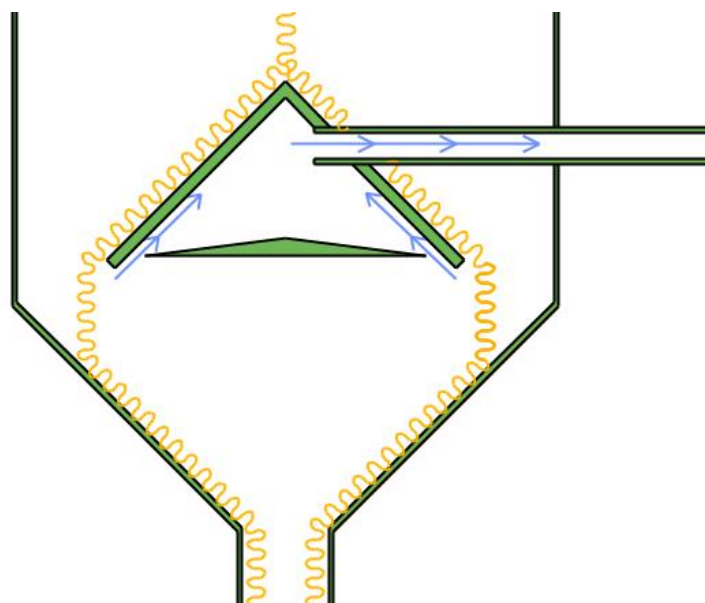
The big issue with the sensors is the paper-like films, which emit the ultrasonic sounds. These films are prone to break under heavy stress, and cannot be used where zircon blasting hits directly. Testing was done on the current blasting equipment whether the sensors can be attached to the nozzles without the films breaking due to zircon ricochets, and the outcome was not positive. After just two weeks of manufacture, the film in the test sensor was found broken and the sensor itself had lost its ability to emit sound. Therefore the idea for sensors was scratched, and the method for determining barrels lengths described above is to be used.



Picture 5 Sketch of an ultrasonic sensor

4.4 Vacuum

Blasting zircon creates a lot of dust, which when escaping the sealed cabinets can cause health issues to employees. A metal shield is placed on the bottom of a blasting cabinet, and a hose from the vacuum sucks dust from underneath it. This allows the zircon beads to drop right to the bottom of the cabinet, while vacuum is able to pick up only the dust light enough to float under the shield. Vacuum cleaner used in the old system was found efficient enough to operate both new cabinets, since, thanks to vertical design of the cabinets; areas to be vacuumed would be much smaller than before.



Picture 6 Sketch of a dust shield within a blasting cabinet

4.5 Dryer

Compressed air in the cell comes from a main compressor system in the factory. Air inside piping is not completely dry and therefore must be processed before it can be used in the blasting system. An electrical dryer is connected to the piping, which removes moist from the air. If the air used in blasting wasn't dried, zircon beads would get lumpy and possibly stick to places it's not supposed to stick on to. Drier is connected to the piping before the air flow is split to various machines in the cell.

4.6 Robot arm

Loading and unloading blasting cabinets was designed to be done automatically with a help of a robot arm. Centered in between two blasting cabinets and a setter, it would unload products from the setter into the cabinets, and subsequently load them back after the blasting was finished. Robot would be armed with a claw, capable of grabbing the adapters attached to barrel and receiver combinations. Robot is a great way to reduce physically stressful labor while, combined with the setter, it creates unmanned production time. Due to zircon dusts' capability to inflict harm on moving parts, a rain coat is designed to protect the robot. While pressurized, it will keep all extra dust from penetrating robot joints and electrical components.

The exact model for the robot is yet to be decided, but it is supposed to have 6 joints and a reachability of about 2m in each direction.

4.7 Plugs

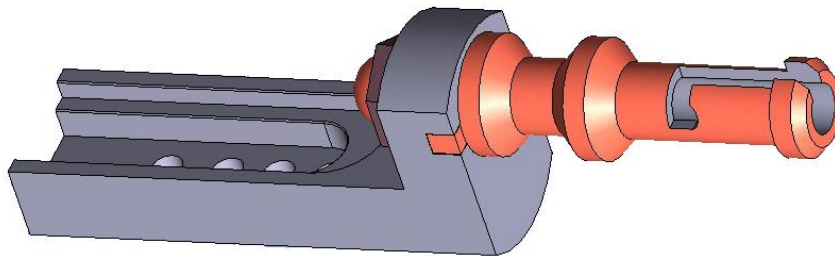
Zircon beads have the capability to destroy rifling inside barrels if left unprotected while blasted. Therefore all barrels have always been plugged from both ends prior to the treatment. Old, horizontal blasting cabinets had a method, where barrels were fixated from the muzzle to prefixed plugs, which rotated along with the products. Barrel housings were plugged by hand with correct size plugs made from natural rubber. When switching to horizontal model of the blasting cabinets, one criterion was to move from fixing barrel muzzles to the cabinet into hanging them only from the adapters. This meant that both ends of the barrel needed to be plugged by hand, and new plugs had to be acquired.

While designing and searching for suitable plugs for muzzles, plugs used for barrel housing were also looked into. The method for removing those plugs after blasting was previously just shooting pressurized air into the barrel, and it was found time consuming and inconvenient, as they often flew away from the table and had to be handpicked from under the table. While correct plugs were successfully found for the muzzles, new plugs for the housings were also picked from the same manufacturer. These plugs have small handles, which makes it easy for the employee to remove

them after blasting. New plugs are made from ethylene propylene diene monomer (EPDM) rubber, and were tested for their resistance to zircon blasting to ensure a long life.

4.8 Adapters

An easy mechanism was needed to attach products to the rotation machinery in the blasting cabinets. The goal was for the adapters to make all receivers end at the same point when hung from inside a cabinet, making it easy for the control to blast those points properly. Previously used adapters were not accurate enough, nor could they be fastened tightly enough for the products not to sway when rotated during blasting. By modifying the old model, new adapters were made with a tight fastening method and a system which allowed all products to be attached so that the end of the receiver settled at same height – regardless of model. A pin was added at the end of each adapter. This would serve as a fastening method to the rotation machinery. Pins for the adapters were designed by an engineering office named InsTiimi Ltd, located in Tampere, which is used as a middle man to design and produce the blasting cabinets.



Picture 7 Early sketch of an adapter with a pin for easy fastening

4.9 Adapter fixator

Pins attached to the adapters needed to be somehow fastened to the rotation mechanism. This was designed using a spring-loaded chuck. Pins attached to the adapters would be inserted into the rotation mechanism, while the chucks locked them into their places. While chucks would hold pins up, they still needed to be tightened so that they would rotate properly, without swaying, so a mechanism to squeeze pins to their chucks was

created. Pins would release with an acting cylinder. Adapter fixation system was designed by InsTiimi Ltd.

4.10 Adapter rotation mechanism

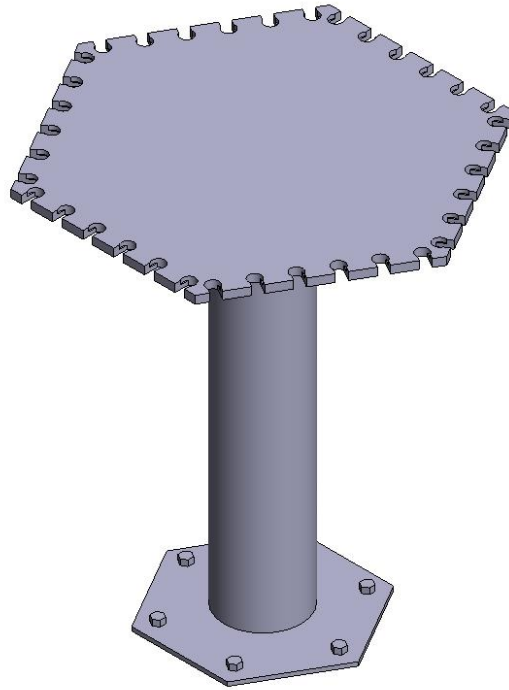
The tooth belt operated and gear motor driven mechanism was placed on top of a blasting cabinet. With the help of the adapter fixator, adapter pins are attached to chucks in the said mechanism. Motor has a stepless drive, but is programmed in the control to operate on three different speeds. One for receivers, one for hunter modeled barrels and one for varmint modeled barrels. The rotation mechanism was designed by InsTiimi Ltd. To prevent zircon from entering chucks and destroying them, it was decided that all sections of the setter must be filled with adapters when loaded, even if there are no products attached to them. Forgetting this rule now and then should not cause a problem, but in the long run it is required from the employee. Cone shaped surfaces were used in the design to guide pins to settle properly inside chucks, and said surfaces were also indented from parts of rotation mechanism. This is to distribute squeezing force into smaller areas, where zircon beads stuck in the middle would break more easily, and therefore wouldn't affect the attachment of products, so that the barrels are always vertical when rotated. Another cone shaped surface inside chucks, without indenting, makes sure that no zircon is allowed to enter.

4.11 Adapter setter

As a part of the plan to produce unmanned production time, an adapter setter was designed. Six sided, table like setter would house up to 36 barrel and receiver combinations attached to their adapters. Products would hang from the adapters muzzle side down.

4.11.1 Stand

Setter has no sensors for tracking products added into it, so all loading must be signed for manually in the control panel. No attachment method was needed for the adapters, as the slots were designed tight enough to prevent products from swaying while being rotated. Since there is a possibility that blasted zircon might cause damage to rotation mechanism of the adapters in the blasting cabinet if the process was started without adapters plugging all the entries, all six spots per side must be filled with adapters, combined with products or not. Dimensional surfaces are kept clean to ensure all adapters fit in their designated slots properly and are easily handled by the robot arm. Cleaning is to be done each time the employee opens the hatch and removes finished products. Preferably, compressed air is not used for this to prevent dust from rising into the cell atmosphere.



Picture 8 Early sketch of the adapter setter

4.11.2 Setter rotation mechanism

Pulse encoder keeps track of the setters' movement, therefore allowing the rotation mechanism to rotate full 360°, without a need to turn around at any time. Controlled by PLC, it communicates with the robot arm for maximum production speed.

4.12 Control station

Each blasting cabinet has its own control station. These include buttons for all mechanisms needed to operate cabinets manually, as well as buttons to teach the control how to perform. Stations have hinges, so they can be turned to the sides of the cabinets when not being used. In addition, there is a small control panel next to the hatch. This panel has buttons only for only the basic necessities: For telling the control whether loaded products had hunter or varmint barrels on them, whether they were black steels or stainless steels and a button to tell the control that loading is done and control is free to rotate the setter.

4.13 Control

The control is operated with Programmable Logic Control (PLC). It controls all the automatic mechanics in the cell:

- Control stations

- Adapter setter
- Robot arm
- Adapter fixator
- Rotation mechanism
- All pneumatic cylinders
- Ultra sound sensors
- Blasting equipment
- Vacuum
- Dryer
- Electrical locks
- Emergency stop –buttons

The program is fully teachable, as well as ready to be operated manually. Deactivating control will cause the robot arm to move into its home position away from passageways.

4.14 Zircon beads

While two cabinets are required in the cell, only one type of zircon bead is used. All zircon is recycled in the system, until it depletes by escaping in products or through seaming. Employee keeps an eye on surface quality on blasted products, and determines when it is time to add some beads into the funnel shaped bottom of a blasting cabinet. Product used in the system is Zirblast B60, with a single bead diameter from 125µm to 250µm.

4.14.1 Soda blasting

Instead of zircon, the option of blasting sodium bicarbonate on product surfaces was taken into consideration. Soda, as a material, is more human friendly and presumably safe, and therefore would have been perfect for our surface treatment material. Unfortunately soda blasting is only designed to remove softer materials from harder surfaces, and the beads are too soft to leave any marks on steel. Therefore they cannot be used to roughen up steel surfaces, and the idea had to be rejected.

5 OPTIMIZING WORK TIME

All production in the factory is clocked for maximizing work efficiency. All costs are held as low as possible, down time is kept at its minimum and work is designed to be done in least possible amount of time. While re-designing blasting cell, the above variables were taken into account. The old system had numerous phases in its work cycle that were either unnecessary or too slow, and this was to be avoided in the future. Optimizing work time is usually seen as a method to make production more profitable, but it also helps employees to cope with work, as under measured amounts of work can easily distract employees from the actual work, thus

making the day feel longer and creating an illusion of a lousy job. Main points to optimize production time are:

- Minimizing costs
- Determining optimal amount of labor required
- Improvement in overall service
- Balancing work tasking
- Minimizing need for excess work
- Ensuring job satisfaction
- Helping with scheduling duty rosters

Optimization in blasting cell was implemented by going through production step by step, and was divided into two categories: How to increase production volumes by adding unmanned production time and how to remove excess work phases from the cycle.

The first thing was to make preparing products easy for blasting. New plugs were bought to meet with new demands, and adapters were designed to fit easily on receivers and were marked by laser to help choosing the right length for certain receiver models. Barrel rack was designed to help with storing products, if the employee found time to prepare work beforehand. Switching from horizontal blasting to vertical removed the need to insert only barrels of same size into the cabinets. This helps the employee, as barrels don't have to be divided into separate groups from barrel carts any more.

One of the most sought into part in the new design was operating with the setter. The setter needed to be available for loading and unloading while the robot was operating with the products on the other side of the fence. By careful planning, a solution was found by using said fence with a locked door, a hatch with safety switches and a smart PLC system to keep track of what is safe and what is not.

The robot arm was, along with the setter, the biggest upgrade to the previous system, and also a huge part in planning to increase both production capacity and unmanned production time. Capable to operate on its own with the help of these two robots, the blasting cell would be able to do its work while employee was out on a coffee break or was engaged in other work related matters. In an optimal situation the employee would be removing plugs and adapters from blasted products and placing them on new ones, followed by unloading the setter and then loading it again, and all this would be continuous with no need for either the employee or the control to wait without acting.

The old blasting cycle had many unnecessary movements that added a lot of time to the production and therefore decreased the capacity. Dividing zircon flow to three nozzles, instead of just two, removed a great proportion from blasting time. Attaching ultra sound sensors to nozzles removed any excess movement from the nozzles, as control became aware of how long the barrels it was supposed to blast were.

6 SAFETY AT WORK

Many factors might affect health of an employee in the zircon blasting cell. When adding automation and machinery with moving parts, it must be taken under recognition that human flesh is no match to motor driven steel that has no sensors for collision. According to directive 2006/42/EY, all machine parts moving with a speed greater than 30 mm/sec must be housed within walls, and must be unreachable by human hand while the machine is being moved. In the thesis, this is implemented by housing the whole blasting systems with a fence, and all doors are equipped with safety switches and system operated locks. The control is taught to seize all moving if any of the safety switches indicate that a door is opened by force, despite the electrical locks. Electrical locks do open when blasting is in progress, but the cabinet doors will stay shut and the robots won't start moving if doors are opened during work cycle. This will allow the worker to attend quick maintenance, such as removing zircon beads from points of high accuracy or check that tubes are not clogged with zircon. Every time the system is restarted or the doors have been opened, an alarm appears on the operating panel indicating that the system will not continue its work unless the employee signs for it. This is done, after checking that the operating area is clear, simply by pressing a button on the panel.

Zircon beads as a product is not scientifically proven to be hazardous to health when consumed by breathing, but still all is done to prevent it from escaping into the factory. With the old system, employees were obligated to wear protective breathing equipment with a mask, filter and a ventilation system. Even thou all seaming in the upcoming blasting system is state of the art; it remains to be seen if the insulation is effective enough to make masks obsolete. The cell itself lacks proper ventilation, which is under development. Fire extinguishers are placed nearby for emergencies.

7 MAINTENANCE

Like any mechanical gadget, blasting cell requires maintenance. Especially with the introduction of automation, removing zircon beads and dust from dimensional surfaces is essential to prolong the life of acquired equipment. The usage of compressed air is not encouraged for said cleaning. With the dust being so light, it will only result in white clouds escaping the cell and settling down anywhere else in the factory, thus only moving the problem to other dimensional surfaces.

7.1 Daily maintenance

Keeping an eye out for the cell is required of the employee. Very little can be done to prevent zircon from building up on surfaces it is not wanted, but wiping those spots with a broom time to time is something that can be done. The door to the cell can, and should, be opened for cleaning every

time it is seen necessary. The cell fence has large holes, which helps the employee to see what is happening in the blasting area.

While zircon in the system is fully recycled, it escapes the system with finished products or through seams. Therefore the employee must be constantly alarmed that the system does not run out of material to blast. Best way to do this is by inspecting surface treated products; low zircon quantity in the system is shown by smoother surface on finished products. Zircon is added to the system by simply pouring it into the cabinets, and this should be done immediately after suspecting a lack of beads in the system.

All control and air flow is planned to be shut down for off duty hours. This is done simply by switching the power off from the control panel, and turning the flow valve from piping.

7.2 Problem situations

Despite all the cleaning, accidents do happen. Even the smallest amount of zircon stuck between two acting robot components can cause a failure in the whole blasting system. Emergency stop buttons are placed nearby the working area, so that the employee has the power to stop all work in case something goes wrong. Such events might occur when beads prevent adapters from settling properly on or in desired slots, cabinet doors don't close all the way, robots collide or rotation machinery gets stuck. Employees are advised to always contact an expert handyman, even if the problem is easy to fix. This is to ensure that handymen have knowledge whether the machinery has been functioning properly or not.

8 ECONOMICS

8.1 Budget

No budget was set for the automation of the blasting cell. Investments are carried out in the factory if:

- Repayment calculations are in order and proven to be profitable.
- The equipment needed is seen as a critical necessity to produce quality products.
- Work safety sections so require.

In this particular case, the repayment calculations turned out profitable enough to ensure that there should be no difficulties in passing the evaluation in the future.

8.2 Investments

The initial idea was to invest in new blasting cabinets, equipment required for the automation and safety gear only. But with calculations so good for the repayment, practically all equipment in the cell will be replaced in the future.

Investments are designed to be carried out in two phases.

Investments included in phase one:

- Due to quantity necessities, new adapters are to be manufactured, as well as the old ones are modified to match the new ones.
- Plugs for both ends of the barrels are being purchased. Luckily a standard model was found efficient enough to fit our needs, and no expensive customization is needed.
- One blasting cabinet, with cylinders, adapter fixator and rotation mechanism as activators.
- Air flow splitter, which divides blasting flow into three nozzles.

Investments included in phase two:

- Safety gear. Containing fence, door, hatch, electric locks, and several signal lights to make employees aware of the situation in hand.
- One blasting cabinet, with cylinders, adapter fixator and rotation mechanism as activators.
- Robot arm with a raincoat.
- Adapter setter with a working rotation mechanism.
- Control and programming for PLC.

8.3 Repayment

Repayment is calculated in intervals, as equipment is acquired step by step. In phase one, where only one blasting cabinet is built for testing, repayment time was calculated to be 2.2 years with the increased production capacity. In phase two, when the cell is fully automated with robot technology and second blasting cabinet, repayment period is estimated to be a little less than 4 years.

9 FUTURE

As it is wise, future investments should be taken into consideration while designing anything new. While designing automation for zircon blasting, two large future investments were implemented into the plan.

9.1 Automation for washing machine

After blasting products with zircon, no beads are allowed to be carried on to assembly. This is why all barrel and receiver combinations are washed

after blasting. On steels about to be blackened, this is done in the blackening cell in one of the pools. But on stainless steels, this is done with a separate washing machine located right next to the blasting cell. In the future, this is supposed to be also automated with the help of the same robot arm as in the two blasting cabinets.

The current washer used in the cell is to be moved to the working area of the robot arm, and a rotating setter is to be installed within the washer. Washer would therefore be able to wash 24 products while new products are blasted at the same time. This way, employee would receive only washed stainless steel products from the blasting circulation.

9.2 Automation for belt grinder

Prior to zircon blasting, all barrels are belt grinded to remove all unwanted flaws and small deformations in the barrel surface. The equipment used for this are getting old in the factory, and an idea came up to design an automated belt grinder which would use same adapters as designed blasting cabinets. As belt grinding needs a human eye to determine whether the grinded surface is smooth enough to be zircon blasted, it cannot be automated with the same system used in the blasting cell (nor will there be room for it). Therefore, the belt grinder would stand outside the blasting cell. Employee would attach adapters to products, belt grind them, and move them to the blasting cell for blasting.

SOURCES

ABB Asea Brown Boveri Ltd. 2010. IRB 2600 Industrial Robot.
[http://www05.abb.com/global/scot/scot241.nsf/veritydisplay/b48a19048143781b482577bb00369543/\\$file/ROBO142EN_B%20LR.pdf](http://www05.abb.com/global/scot/scot241.nsf/veritydisplay/b48a19048143781b482577bb00369543/$file/ROBO142EN_B%20LR.pdf)

Borrel Fontelles, J. & Winkler, H. 2006. Directive 2006/42/EC of the European parliament and of the council of 17 May 2006 on machinery, and amending Directive 95/16/EC: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:157:0024:0086:en:PDF>

Cabinet of Finland. 2008. Government Decree on the safety of machinery (400/2008): <http://www.tyosuojelu.fi/fi/a20080400/2414>

Competitive Edge Coating Inc. n.d. Sandblasting & Material Blasting Info & Pricing.
http://www.competitiveedgecoatings.com/pages/material_blasting.php

European Commission Enterprise and Industry. 2012. Guide to application of the Machinery Directive 2006/42/EC, §169 Guard.

http://ec.europa.eu/enterprise/sectors/mechanical/files/machinery/guide-appl-2006-42-ec-2nd-201006_en.pdf

Festo Didactic GmbH & CO. 2002. Programmable Logic Controllers: Basic Level. http://www.festo-didactic.com/ov3/media/customers/1100/093311_web_leseprobe.pdf

Kramer Industries, Inc. n.d. Abrasive Blasting Media for Sandblasting Equipment. <http://www.kramerindustriesonline.com/blasting-media.htm>

Nurminen, P. 2012. Budget proposal (Robot preparedness). Insinööritoimisto InsTiimi Oy, BUDJETTITARJOUS 1 (Robottivalmius). 7.5.2012

Nurminen, P. 2012. Budget proposal (Robot cell). Insinööritoimisto InsTiimi Oy, BUDJETTITARJOUS 1 (Robottisolu). 7.5.2012

Scott, E. 2013. #1 Website Dedicated to Sandblasting Information. <http://www.sandblasterinfo.com/>

SEPR Saint-Gobain ZirPro. 2012. Zirblast: Technical data sheet. <http://www.zirpro.com/uploadedFiles/SGZirpro/Documents/SGZirPro-Zirblast-TDS-201204-E.pdf>

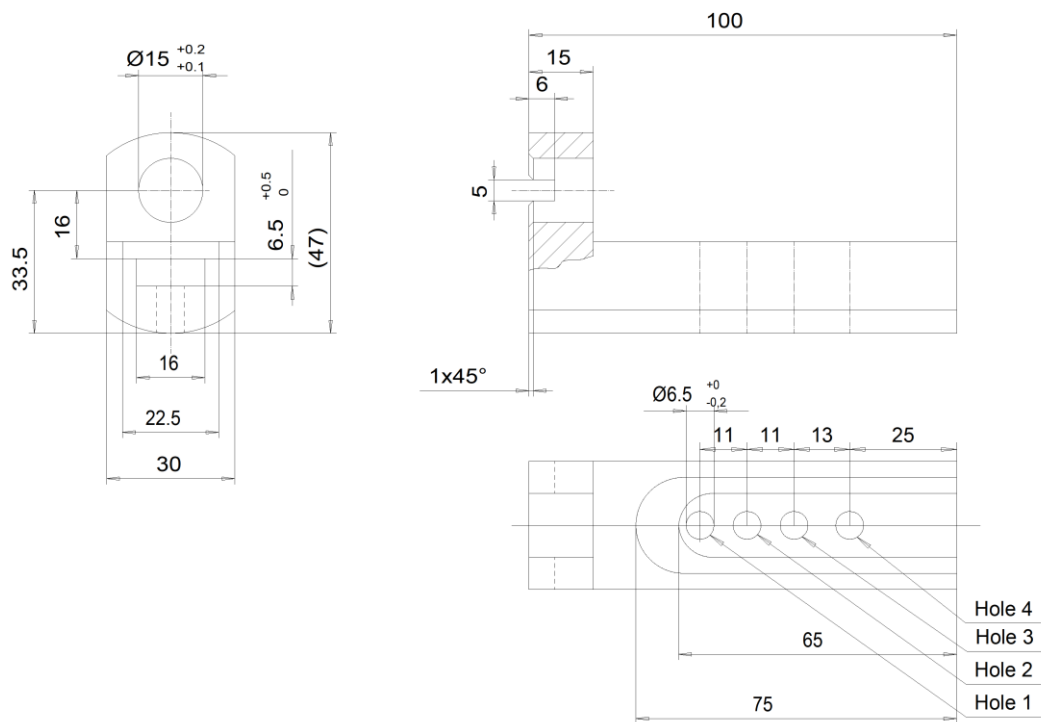
United States Environmental Protection Agency. 1997. Abrasive blasting. <http://www.epa.gov/ttn/chief/ap42/ch13/final/c13s02-6.pdf>

Wikipedia. 2011. Abrasive Blasting. http://en.wikipedia.org/wiki/Abrasive_blasting

CALCULATIONS FOR ADAPTER MEASUREMENTS

Receiver	R length		RF to AH		AB to AH		H spot	AB to RF		Optimum		Diff.	
T3 RH	226	mm	205,5	mm	51	mm	2	256,5	mm	261	mm	4,5	mm
T3 LH	226	mm	205,5	mm	51	mm	2	256,5	mm	261	mm	4,5	mm
85/XS	192,5	mm	179,5	mm	75	mm	4	254,5	mm	261	mm	6,5	mm
85/S	213,5	mm	200,5	mm	62	mm	3	262,5	mm	261	mm	-1,5	mm
85/M	224,5	mm	211,5	mm	51	mm	2	262,5	mm	261	mm	-1,5	mm
85/SM	213,5	mm	200,5	mm	62	mm	3	262,5	mm	261	mm	-1,5	mm
85/L	233,5	mm	220,5	mm	40	mm	1	260,5	mm	261	mm	0,5	mm
A7/S	213,5	mm	200,5	mm	62	mm	3	262,5	mm	261	mm	-1,5	mm
A7/M	224,5	mm	211,5	mm	49	mm	2	260,5	mm	261	mm	0,5	mm
TRG-22	208,5	mm	202	mm	62	mm	3	264	mm	261	mm	-3	mm
TRG-42	228,5	mm	222	mm	40	mm	1	262	mm	261	mm	-1	mm

R = Receiver A = Adapter F = Front side B = Back side H = Hole for the screw



CLOCKING ZIRCON BLASTING

Product:	T3 Cal. 65x55	
Barrel length:	540	mm
Receiver length:	226	mm
Combined:	766	mm

Current equipment: Cabinet 1, able to blast 6 products

Workphase	Interval		Notes:
Displacement	0,348	min	Nozzles halt at the end of barrels for about 0,05 min
Barrels 1 & 2	2,111	min	Nozzles halt at the root of barrels for about 0,05 min
Displacement	0,523	min	Nozzles halt at the cartridge chambers for about 0,05 min
Barrels 3 & 4	2,13	min	Speeds reduced on receivers
Displacement	0,523	min	
Barrels 5 & 6	2,12	min	
Displacement	0,208	min	
Total	7,963	min	

New system (fully operational), rough calculations:

Workphase	Interval		Notes:
Barrels 1 & 2 & 3	2,12	min	2 cabinets operational at all times
Displacement	0,35	min	12 products blasted (compared to 8 in the old system)
Barrels 4 & 5 & 6	2,12	min	Speeds reduced on receivers
Displacement	0,2	min	
Total	4,79	min	

Results:		
Time cut / 6 barrels:	3,173	min
Time cut / barrel:	0,529	min
Percentual cut:	39,85	%

Nozzle speeds:			Rotation speeds:		
HUN barrel	9,2	mm/sec	HUN barrel	135	rpm
VAR barrel	7,6	mm/sec	VAR barrel	88	rpm
Receiver	6	mm/sec	Receiver	40	rpm